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# Relationships between Avian Diversity and Vegetational Parameters in Forested Patches of the Tualatin Mountains, Oregon

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THESIS APPROVAL

The abstract and thesis of Jerry Sexton Fugate for the Master of Science in Biology were presented April 27, 1994, and accepted by the thesis committee and the department.

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# ABSTRACT

An abstract of the thesis of Jerry Sexton Fugate for the Master of Science in Biology presented April 27, 1994.

Title: Relationships Between Avian Diversity And Vegetational Parameters In Forested Patches Of The Tualatin Mountains, Oregon.

The effect of contiguous forested habitat area on local avian diversity and species richness in the Tualatin Mountain area of northwestern Oregon was investigated. Observations of eight forested stands representing seven area values (1, 2, 7, 14, 18, 24 and 40 hectares) were made during the spring and summer of 1991 and 1992. The variables measured were chosen in an attempt to show possible relationships between vegetation factors, spatial patterns and bird communities. Kendall's rank correlation coefficients were used to analyze the data. Avian species richness and diversity were significantly correlated with forest stand (patch) size. The only significant correlation between avian species richness and diversity and vegetation measures was with percent shrub layer cover.

It seems likely that avian diversity and richness are increased due to the presence of species that can utilize the interior and edges of forest stands along with species which depend upon true forested interior. When forested patch size drops below a critical area, the patch becomes all edge. Interior species are absent due to increased predation and the inability to compete with interior-edge species. Edge effect may be a contributing factor to variation in diversity of birds. The correlation of percent shrub layer cover with avian measures is accompanied by a correlation of percent shrub layer cover with distance from edge. This suggests further investigation is required to assess

this relationship. Studies conducted in the northeastern and north central United States have shown a similar relationship between bird communities and forest patch size.

# RELATIONSHIPS BETWEEN AVIAN DIVERSITY AND VEGETATIONAL PARAMETERS IN FORESTED PATCHES OF THE TUALATIN MOUNTAINS, OREGON

by

JERRY SEXTON FUGATE

A thesis submitted in partial fulfillment of the
requirements for the degree of

MASTER OF SCIENCE
in
BIOLOGY

Portland State University
1994

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## ACKNOWLEDGMENTS

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# INTRODUCTION

Studies of relationships between composition of bird communities and habitat structure show that the degree of habitat fragmentation is a key factor in determining avian species diversity. These studies show that as the degree of habitat fragmentation increases avian species diversity decreases. Most of these studies have been conducted either in coniferous or mixed conifer-hardwood forests of eastern and north central North America (e.g., Blake and Karr 1984, Hopkins 1955, MacArthur and Wilson 1967) or in riparian communities of the deserts of the southwestern United States (Rice et al. 1983). The goal of this study is to see if habitat fragmentation and avian diversity are similarly related in the forested area in and near Portland, Multnomah County, Oregon.

Dense coniferous forests dominate much of the Pacific Northwest west of the Cascade Mountains. Ecological studies in this region have focused on questions surrounding the impacts of logging and livestock grazing on local ecosystems. Understanding the interaction of habitat fragmentation and spatial relationships in these ecosystems is a high priority in the growing discipline of conservation biology (Soulé and Kohm 1989). As human populations continue to grow, there is increasing interest in the impacts of residential and commercial development on adjacent forested areas.

Gaining insight into the functional relationships between avian community structure and habitat requires one to identify components of the habitat to which the birds respond. Galli et al. (1976) studied relationships between foliage height diversity (diversity of plant species at different layers of vegetation from canopy to ground level), forest patch size and "geographic section" and bird species richness in an investigation of avian distribution patterns in central New Jersey. The Galli et al. (1976) study area was divided into northern, central and southern geographic sections in an attempt to control for differences due to location. Galli et al. (1976) found that bird species *richness* (number of bird species) was correlated significantly only with forest patch size and a combination of patch size and geographic section. MacArthur and co-workers (MacArthur et al. 1962, MacArthur 1964) showed that heterogeneity of habitat, as measured by increased foliage height diversity (FHD), was strongly associated with an increase in bird species *diversity* (a more complex measure than richness, see p. 14). However, Galli et al (1976) seems to refute this by demonstrating a relatively homogeneous internal FHD for her plots and a significant positive correlation between bird species richness and forest size.

Rice et al. (1983) argued that FHD is the most important habitat factor as a predictor of avian species community structure. These authors also demonstrated that the importance of FHD varies in significance between species, and for those species for which it was statisically significant, it was the primary habitat selection factor.

Ambuel and Temple (1983) analyzed moisture-nutrient and successional gradients along with FHD and compared these factors with bird diversity and forest patch size using principle components analysis. They demonstrated that vegetational structure varied independently from forest patch area. They also showed that the density of birds classed as long range migrants increases with patch area. This area-dependent relationship may account for increases in overall bird diversity in larger patches.

Other work (Askins et al. 1986, Blake and Karr 1984) suggests that the increase in avian diversity is a direct result of the area of a patch of habitat and the proportion of that patch that is edge. A larger patch would have greater diversity than a smaller patch of similar shape. Edge effects on plant communities have shown some significant impacts on species composition (Harris, 1984; Reese & Ratti, 1988). Perhaps the area-dependence of avian communities is related to plant communities' responses to edge effects. If this is so, it would lend support to the importance of FHD in predicting avian community structure. One way to test this is to investigate relationships between avian diversity and changes in plant community structure.

Several questions were addressed in this study. First, is there a significant difference in avian species diversity between the stands sampled? Second, is there a significant variation in the plant community structure associated with stand size and, if so, is the variation also associated with distance from edge? And finally, if there is variation in avian community diversity is it associated with vegetational measures, the stand size or distance from edge?

It would be very helpful in formulating planning and development policies if firm relationships between spatial patterns and their effects on ecosystems can be established.

# STUDY AREA

## LOCATION

The study area, located in Multnoman County in northwestern Oregon, is bordered by Columbia County on the north, by Washington County on the west, by U.S. Highway 30 on the east (Figures. 1 and 2), and the city of Portland's Forest Park boundary with the residential Northwest Portland on the south. The entire area under consideration is approximately 6000 hectares (ha), of which Forest Park makes up some 2000 ha.

The study area primarily includes the Tualatin Mountains, the southern end of which are commonly referred to as the Portland West Hills. The area consists of a narrow, northwest trending, complexly faulted range that rises to about 440 m (1400 ft). Forest Park accounts for the largest tracts of uninterrupted forested habitat.

## GEOLOGY

The Tualatin Mountains were created some 13 million years ago as a result of the same geologic activity in the late Miocene that also formed the Cascades (Trimble 1963). Prior to the uplift of the Tualatin Mountains, a layer of silt carried in from the Columbia River flood plain capped Columbia basalts which were laid down approximately 16 million years ago (Trimble 1963). The soils in the area are primarily Goble and Cascade Silt Loams and Wauld Very Gravelly Loam capped by a rich organic layer. A hard fragipan of low permeability runs throughout the uplifted area. This layer of brittle soil at a depth of 70 to 120 cm beneath the silts results in a perched watertable above the

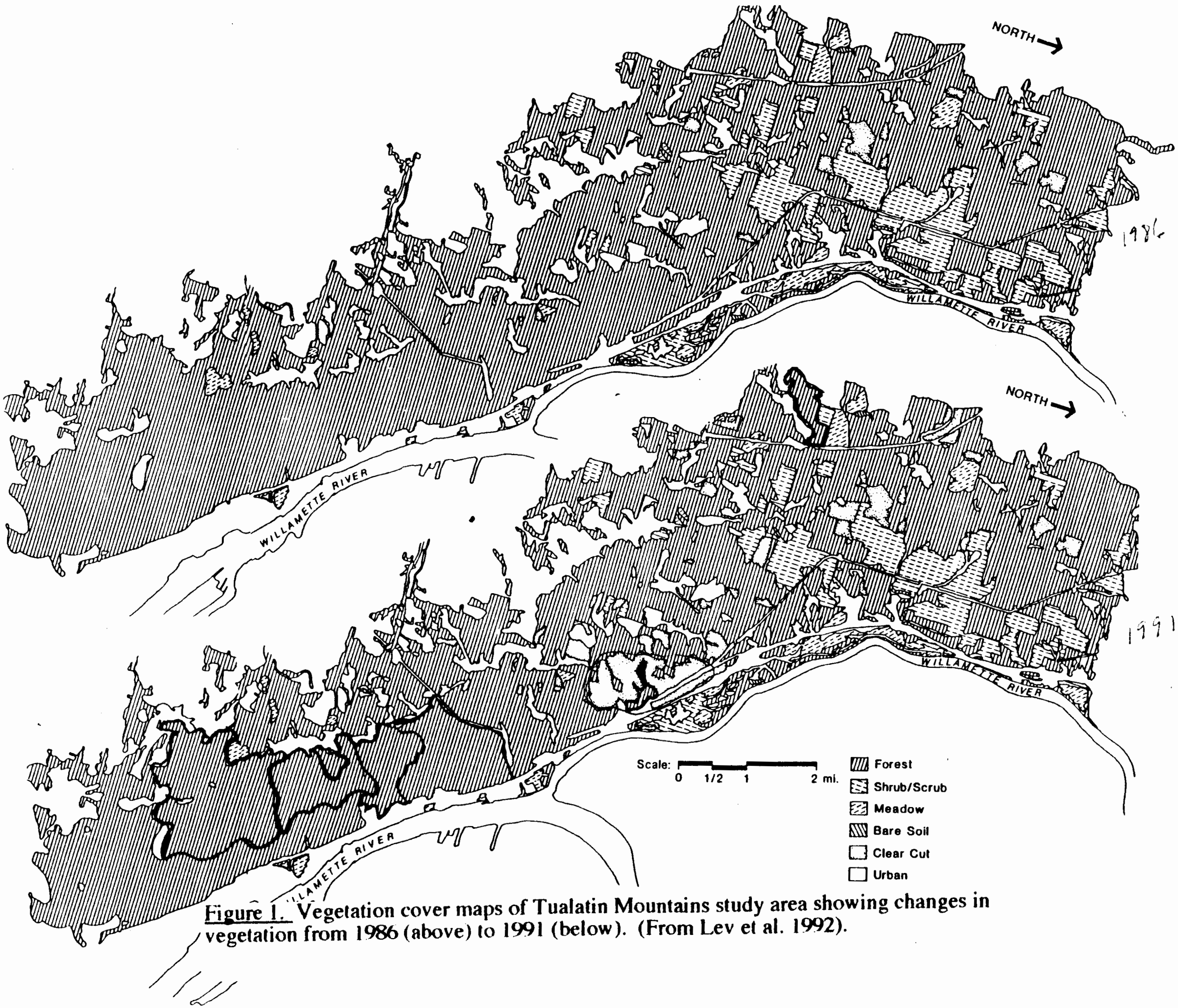


Figure 1. Vegetation cover maps of Tualatin Mountains study area showing changes in vegetation from 1986 (above) to 1991 (below). (From Lev et al. 1992).

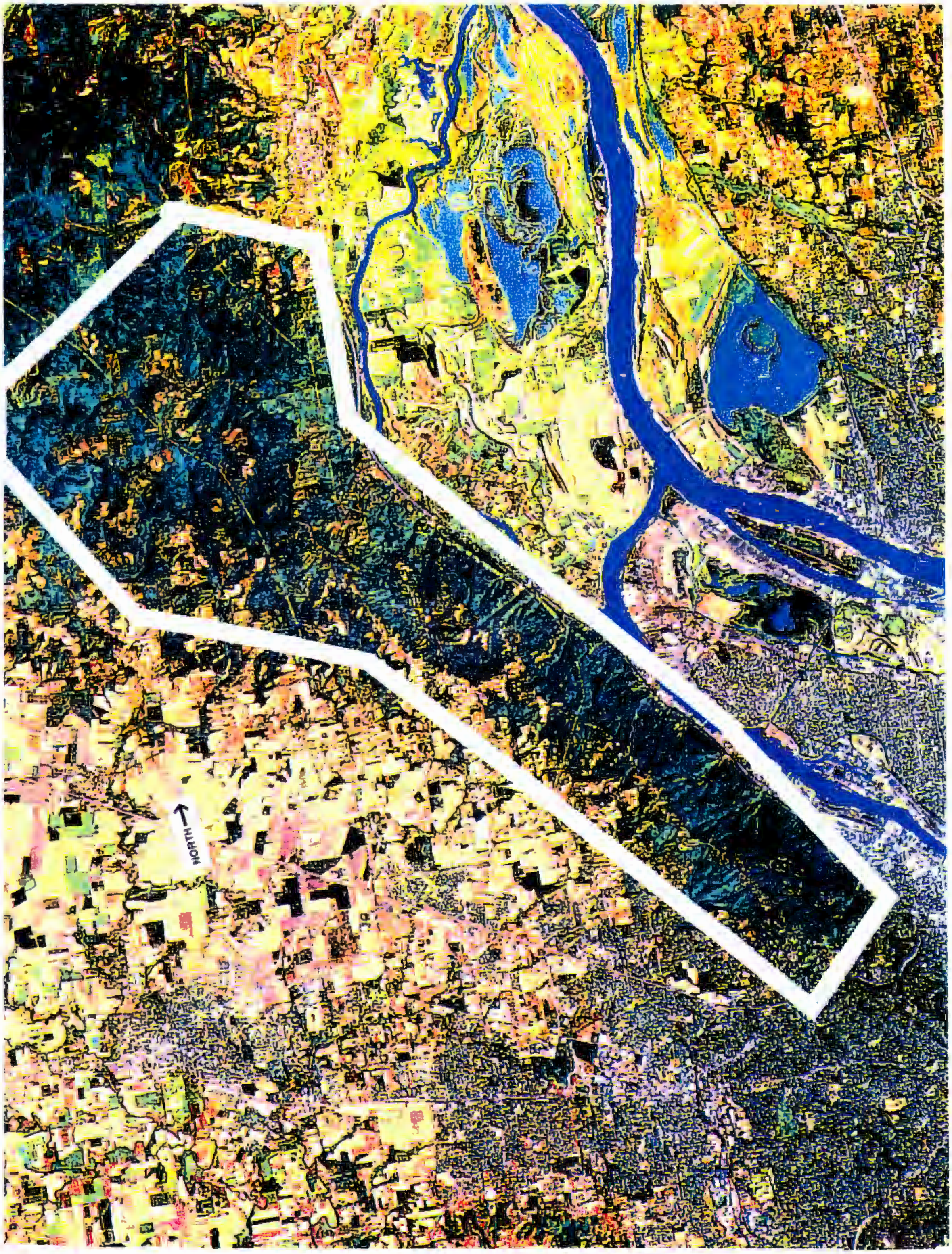


Figure 2. Satellite photograph of Tualatin Mountains (color enhanced). Study area is outlined in white. (From Lev et al. 1992).

regional watertable. The combination of these edaphic factors limits the effective rooting depth of plants in much of the area (Green 1983).

## VEGETATION

Much of the Tualatin Mountains was originally forested with vegetation characteristic of the Western Hemlock Zone of the Oregon Coast Range (Davies 1980, Franklin and Dryness 1973). The current plant association is consistent with several seral stages of the *Tsuga heterophylla/Polystichum munitum* association described by Franklin and Dyrness (1973). In the past century the region has been altered by human activities such as logging, agriculture, extraction of mineral aggregate and, more recently, residential development. These changes are reflected in current vegetation patterns, as most of the area is in some mid-aged seral stage (Franklin and Dyrness 1973, Lev et al. 1992).

Pollen and macrofossils from late Holocene deposits in nearby southwestern Washington reveal plant communities that resemble the predicted climax community for the study area (Barnosky 1984). This description is consistent with reports from early European observers (Davies 1980).

This site is of special interest because one-third of it is made up of Forest Park, the largest forested park entirely within an incorporated city's boundaries in the United States. The proximity of a large natural area to a major metropolitan center offers an unequaled opportunity to observe relationships between plant and animal communities, human activities and landscape patterns.

## METHODS

Eight transects were established by selecting a random starting point in contiguous forested patches ("stands") of seven different sizes. Six of these transects were 500 meters long. In two stands which were smaller than 2 hectares the transect lengths were limited to 200 meters in order to avoid double sampling of overlapping plots. Stand area was estimated by tracing an outline of the forested patches from false-color infrared aerial photographs onto a sheet of paper (Lev et al. 1992). The outlines were then cut out and weighed to the nearest $10^{-4}$ g on an analytic balance. Area was determined ($\pm$ 0.5 ha) by dividing the weight of the sample cut-outs into the weight of a cut-out of known area and multiplying the quotient by the scale area represented by the known cut-out. All the cut-outs were obtained from the same sheet of paper to minimize error.

Transects were located by identifying the beginning of the patch as the point at which it met the "edge " as approached from the nearest access point (e.g. road, meadow, clearcut, etc.). A random numbers generator was used to determine the beginning of each of the transects. A three digit number was used to determine the distance in meters from the starting point as defined above. In the case of patches <100 meters long, the first two digits were used to determine the distance to the beginning of the transect.

## TRANSECT LOCATIONS

Transect #1: This transect begins on firelane 7 at point 805 m (0.5 miles) from the intersection of NW Springville Road and NW Skyline Blvd (483 m (0.3 miles) from the gate marking the beginning of firelane 7). The transect runs on a bearing of approximately 40° from true North for 500 m downslope; roughly following the ridgeline.

Transect #2: The transect begins at the rear of the residence at 6720 NW Skyline Blvd. The first plot , "P 1", is located 255 m (0.16 miles) from the edge of NW Skyline at its intersection with NW Springville Rd. . The intersection of NW Springville Rd. with NW Skyline on the west does not line up exactly with the eastward extension of NW Springville Rd., which is located about 60 m to the north. At P 1 the transect takes a bearing of 62° from true North for 400 m with the last plot located roughly 15 m SW of the gate at the head of Firelane 7.

Transect #3: This transect begins approximately 20 m north of Firelane #9 where a spur of the firelane dead ends behind homes on NW Wylark St. above Linnton on US Hwy 30. From the edge of the residences it runs 500 m upslope (west) on a compass bearing of 238° from true North. The transect ends (P 5) at a point adjacent to Firelane 10, 250 m downslope from the intersection of Firelane 10 and NW Germantown Rd.

Transect #4: This transect begins at the edge of a clearing adjacent to and south of Firelane 15 at its intersection with NW Skyline Blvd. The first plot is located 100 m from the edge of the clearing and runs roughly parallel to the firelane for 300 m on a bearing of 40° from true North. At a point approximately 50 m before the final plot (P 5) the transect crosses Firelane 15.

Transect # 5: Located in a stand of planted Douglas fir (*Pseudotsuga menzeisii*), the beginning transect is located on the west side of the stand, 105 m south of NW Johnson Rd. at the edge of an open meadow (a clear cut). The edge is bordered by a dirt road that is located where it meets NW Johnson Rd., roughly 200 m east of the Multnomah/Washington county line. The transect bears 90° from true north..

Transect # 6: This transect consists of two plots only. These are located in a small patch of forested area adjacent to the City of Portland Water Bureau's Willatin water tank. The tank is located in a small park area approximately 100 m east of NW Skyline Blvd. The study plots were placed 100 m apart along the forested edge on the west side of the cleared park area. The first plot was located roughly 25 m south of the water tank and the second plot was established 100 m north along the forest edge (Figure 3.)

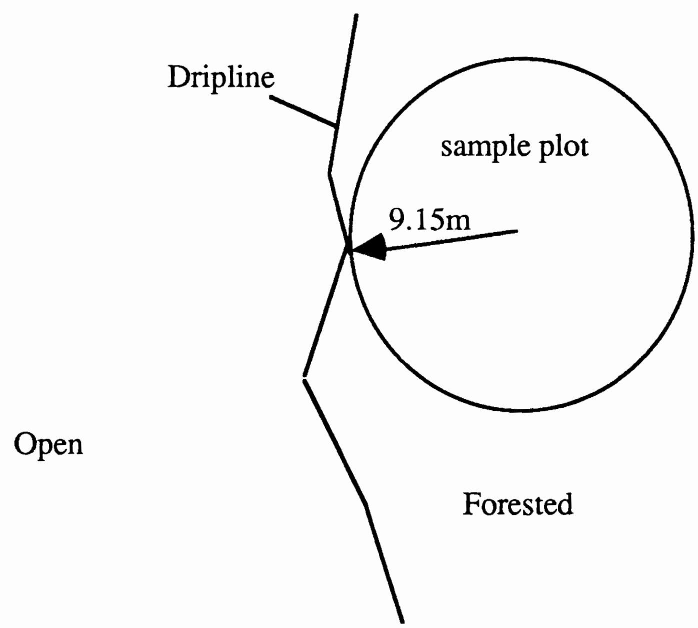


Figure 3. Configuration of plots located at 0 meters from a forested edge.

Transect # 7: This transect was located in Portland's Forest Park, beginning at point on the Wildwood Trail 135 m northwest of its interesection with the Wild Cherry Trail. The transect follows a compass bearing of 335° from true north.

Transect # 8: The beginning of this transect was located approximately 500 m upslope (east) of US Highway 30 and approximately 400 m north of the Angell Brothers Quarry operation, located at 14545 NW St. Helens Rd. The transect bears 305° from true north. Due to the small area of this stand only three study plots were established in it.

All plots were 18.3 m (60 ft) diameter circles centered on points set 100 m apart. A circular plot of 9.15 m radius has an area of 263 $m^2$. This size falls within the range estblished for tree sampling by Carey and Spies (1991). Plots that were located at 0 m from the nearest edge are centered on a point 9.15 m (30 ft) from the dripline of the forest canopy at the edge of the forested stand; thus only forested area was sampled (Figure 3).

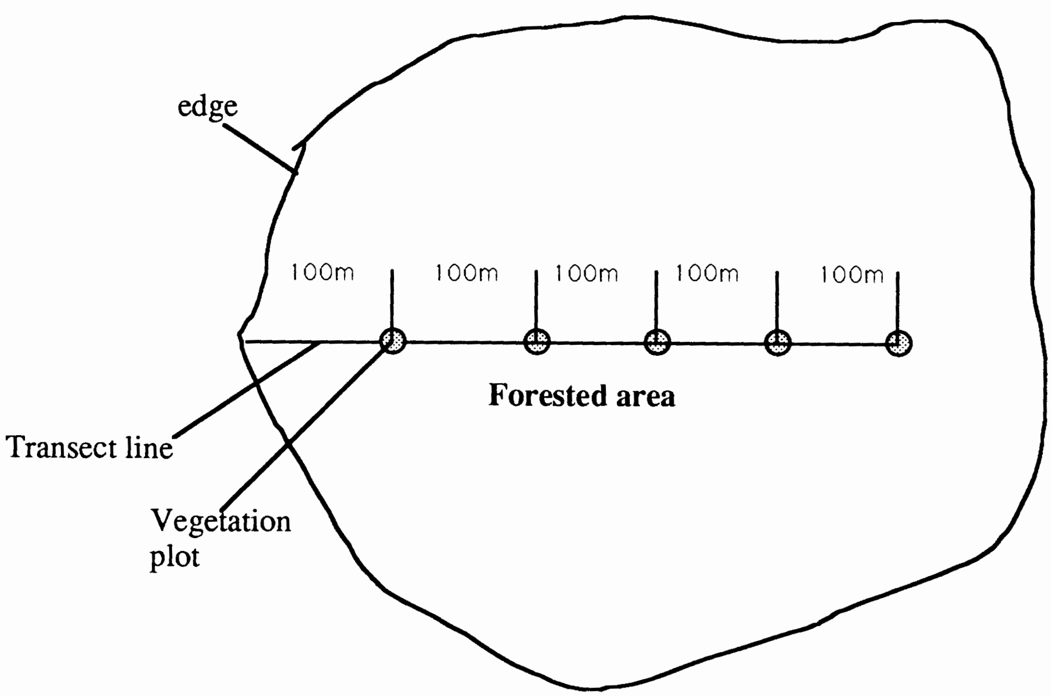


Figure 4. Transect layout showing arrangement of vegetation plots

## VEGETATION SAMPLING

Five circular plots 18.3 m (30 ft) in diameter and centered on points 100 m from the beginning of each transect and at 100 meter intervals were established for vegetation sampling (Figure 4). It was not possible to fit five plots into the two smallest stands so three plots were established in Transect 8 and two on Transect 6. Individual plants were classified as trees, shrubs and ground cover. Trees were defined as woody perennials >1.5 m tall, shrubs as woody perennials between 0.5 m and 1.5 m tall and ground cover as herbaceous and low woody species ≤ 0.5 m tall (Askins et al. 1986). Estimates of cover were made for each structural layer using circular matrix density cards (Terry and Chileingar 1955).

The distance to the nearest edge was measured using a hipchain or metric tape. Distances were recorded to the nearest 10 m. Each transect started with a plot centered on a point 9.1 m from the vegetational discontinuity that comprised the edge, so that the sample plot was just within the edge of the forested stand. In most cases the vegetational discontinuity was easily defined because the edges were artifacts of human activity such as clearcuts, roadways, powerline rights-of-way or agricultural fields.

The percent coverage contributed by the foliage of each species was estimated for each vegetational layer. Only plant species contributing more than 1 % were included in species counts. Estimations of total tree canopy cover included the cover contributed by all foliage over the plot, regardless of whether the stem fell within the boundary of the plot. Percent tree canopy cover was then converted to cover class following Daubenmire (1968). This was done because precise estimates of tree cover are difficult and time consuming to obtain and were not deemed absolutely necessary for the purposes of this study.

TABLE I

DAUBENMIRE COVER CLASSES AS APPLIED TO TREE COVER

| Range of cover (%) | Class |
|---|---|
| 95-100 | 6 |
| 75-95 | 5 |
| 50-75 | 4 |
| 25-50 | 3 |
| 5-25 | 2 |
| 0-5 | 1 |

## SAMPLING BIRD POPULATIONS

Bird populations were surveyed using transect sampling methods similar to those described by Emlen (1977). Surveys of birds were conducted between 23 June and 12 July 1991 and between 24 May and 11 June 1992. A strip transect 500 m long (200 m in the smallest two patches) was surveyed along each of the main transect lines that were established for sampling of vegetation. These transects were divided into 100 m sections. When an edge was encountered, the transect line was turned at 45° to a line roughly tangent to the edge. Each transect was surveyed twice, once on two consecutive mornings. All sightings, song, calls, nests, and excavations observed were recorded. When a flock was encountered, an estimate of the number of individuals was made. Common and scientific names of birds observed in this study are listed in Appendix A.

Bias in this method results from differential detectability of species; quieter or more cryptically colored birds tend to be underrepresented in comparison to louder species or those more easily seen (Emlen 1977).

All censusing was conducted within two hours of sunrise on days with no rain, fog or high winds. I alone collected all avian data, thereby eliminating confusion that might arise from different workers' abilities to detect different species. Surveys conducted in 1992 were conducted earlier than in 1991. Because of the mild winter and an unusually warm, dry spring in 1992, many migrants may have arrived in the study area earlier in 1992 than in 1991. However, a Student's t-test of the data from 1991 and 1992 revealed no significant difference in the data for the two years, so the data were pooled for analysis.

## ANALYSIS OF DATA

Because some of the assumptions of homogeneity of variance ($F_{max} = 7.26$, $a = 7$, $n = 4$) and independence could not be met, nonparametric statistics were employed to analyze relationships between stand size and vegetation factors. Kendall's rank correlation coefficient employs the ranking of variates and calculates a coefficient of rank correlation (Sokal and Rohlf 1987). In this case, the ranks of species richness and amount of cover at the three structural levels versus the ranks of stand area should give some idea of the association between these measures. Additionally, comparing species richness and Shannon's Index of diversity for bird populations with stand size and the vegetational factors attempts to identify covariation of these factors that may indicate association between them. The definition of species richness used here is the number of species observed. Shannon Index of diversity is defined as,

$$H' = -\sum_{i=1}^{s^*}\left(p_i \ln p_i\right),$$

where H' is the average certainty per species in an infinite community made up of $S^*$ species with known proportional abundances $p_1, p_2, \ldots, p_{s^*}$. $S^*$ and the $p_i$'s are the population parameters. This expression is indicated by Pielou (1966) as appropriate when the diversity is estimated from a sample. Essentially, H' predicts the probability that an individual drawn at random from a collection of $S$ number of species will belong to a given species. The larger H' is, the less likely that any individual chosen at random will belong to the same species as any other. A greater uncertainty of getting two individuals of the same species for any given sampling event theoretically means that the collection of species is more diverse. Finally, Kendall's rank correlation coefficients were computed for associations between bird species richness and diversity and vegetation measures.

Correlations were considered significant at $p \leq 0.05$. Calculations were made on a Macintosh Classic computer using StatView Student statistical analysis software (© 1991 Abacus Concepts, Inc.).

## RESULTS

Tree species richness, ground cover species richness and percent gound cover were not significantly correlated to the independent factors of stand size and distance from edge. Shrub species richness was found to be significantly correlated with distance from edge ($p < 0.05$) but not with percent shrub cover. Both shrub species richness and percent shrub cover were found to be positively correlated with stand size (both at $p < 0.001$) (Table II).

Bird species richness ($p < <0.001$) and Shannon's Index ($p < 0.0001$) were significantly correlated with stand size. Distance from edge was significantly correlated only with avian species richness ( $p < 0.01$). A significant correlation ($p < 0.05$) was also found between Shannon's Index and percent shrub cover and between pecent shrub cover and bird species richness ($p < 0.05$) (Table II). No other significant correlations were found.

TABLE II

KENDALL RANK CORRELATION COEFFICIENTS
STAND AREA VERSUS VEGETATION AND BIRD SPECIES VARIABLES

| FACTOR | DISTANCE FROM EDGE | | STAND AREA | |
|---|---|---|---|---|
| | Corrected t | Significance | Corrected t | Significance |
| #Tree spp. | 0.113 | n.s. | 0.145 | n.s |
| # shrub spp. | 0.228 | p<0.01 | 0.502 | p<0.001 |
| # ground cover spp. | -0.38 | n.s | -0.103 | n.s |
| tree cover class | 0.082 | n.s. | 0.152 | n.s. |
| % shrub cover | 0.145 | n.s | 0.454 | p<0.001 |
| % ground cover | -0.185 | n.s | 0.143 | n.s. |
| # bird spp. | 0.325 | p<0.01 | 0.527 | p<0.0001 |
| Shannon's index | 0.136 | n.s. | 0.437 | p<0.0001 |

n.s. = not significant at $p \leq 0.05$

TABLE III

KENDALL RANK CORRELATION COEFFICIENTS
BIRD SPECIES RICHNESS AND SHANNON'S INDEX VERSUS VEGETATION FACTORS

| FACTOR | BIRD SPECIES | | SHANNON'S INDEX | |
|---|---|---|---|---|
| | Corrected t | Significance | Corrected t | |
| Significance | | | | |
| # tree spp. | -0.341 | n.s. | -0.009 | n.s. |
| # shrub spp. | 0.202 | n.s. | 0.105 | n.s. |
| # ground cover spp. | 0.470 | n.s. | -0.01 | n.s. |
| tree cover class | 0.049 | n.s. | -0.048 | n.s. |
| % shrub spp. | 0.306 | p<0.05 | 0.291 | p<0.05 |
| % ground cover | 0.191 | n.s. | 0.134 | n.s. |

Because of sample size limitations, no extensive analysis of relationships between avian species between a given species of bird and the vegetation or independent variables was conducted. A correlation matrix for abundance (number of individuals) of each bird species compared to stand size was generated with the understanding of its limited application. Occurrence of orange-crowned warbler ($p = .05$), red-breasted nuthatch ($p < .05$), and the brown creeper ($p < .05$) were significantly correlated with stand size.

# DISCUSSION

The results suggest a three-way relationship between bird species diversity and richness, stand size and shrub layer that may have ecological significance. The correlation of certain avian and shrub layer values with stand size may reflect an interaction between these three parameters. It may be that I did not collect data in a way that can elucidate which factor is of primary importance. Examination of the other variables of vegetation and distance from edge reveal that shrub species richness is significantly correlated with distance from edge, and avian factors are not. It is possible that the correlation between percent shrub cover and avian species richness and diversity is coincident to stand size, and that shrub cover is related to a factor that is not directly affecting avian community structure. One approach to address this question would be to repeat the bird surveys on study plots that were selected so as to control for shrub layer values. Dividing the vegetation into five structural layers instead of three or collecting photometric data on foliage height diversity, might also help to answer this question. These techniques would provide more detail about the vegetational structure and perhaps show to which components, if any, the birds respond.

As predicted from work elsewhere (Ambuel and Temple 1983, Askins et al. 1987, Blake and Karr 1984), it appears that a clear positive correlation exists between forest stand size and both avian species richness and diversity. The degree of this relationship may be related to certain vegetational factors. It is highly probable that the importance of vegetation in predicting bird diversity varies with the seasonal changes, as well (Rice et al. 1983), though I have no data on this for the Tualatin Mountains.

MacArthur and co-workers (MacArthur et al. 1962, MacArthur 1964) demonstrated that foliage height diversity (FHD) strongly affects avian diversity in a variety of forested and grassland sites throughout the eastern United States. However, these studies (MacArthur et al. 1962 and MacArthur 1964) did not include habitat patch area as a factor. Subsequent literature (MacArthur and Wilson 1967) cites examples that included forest patch area and show a positive species diversity-area relationship. Rice et al. (1983) obtained results that support FHD as a significant predictor of bird diversity in riparian habitat of the Colorado River Valley of Arizona. But again, Rice et al. (1983) did not include patch size as a factor.

There is growing evidence that spatial patterns themselves, rather than FHD, are predictors of changes in bird species diversity (Askins et al. 1987) and that a main component of this spatial relationship is forest stand area (Ambuel and Temple 1983, Galli et al. 1976). Askins et al. (1987) used other pattern relationships as well as stand area in analyzing forest communities in Connecticut. They also classified species of birds, according to habitat preference, as forest interior birds and interior-edge birds and noted that interior species tended to be long range migrants. Several long range migrants occur in the study area (Peterson 1990)(Table IV).

TABLE IV

PARTIAL LIST OF
LONG RANGE MIGRANTS KNOWN TO OCCUR IN
THE TUALATIN MOUNTAINS

| Rufous Hummingbird | *Selaphorus rufus* |
|---|---|
| Olive-sided Flycatcher | *Contopus borealis* |
| Pacific slope Flycatcher | *Empidonax difficilis* |
| Western Wood Peewee | *Contopus sordidulus* |
| Swainson's Thrush | *Catharus ustulatus* |
| Western Tanager | *Piranga ludoviciana* |
| Blackheaded Grosbeak | *Pheucticus melanocephalus* |

Askins et al. (1987) found that interior species richness was related to area factors and that vegetation factors were significant predictors of interior-edge species richness. In fact, interior edge species richness appeared to be negatively associated with stand area. The authors concluded that stand area ("patch size") is the best predictor of avian species abundance and richness and that this is due, in part, to the decrease in numbers of interior species in smaller patches combined with the complete absence of certain "area sensitive" species in patches below a threshold area. According to edge effect studies (Harris 1989, Lemkuhl and Ruggiero 1991, Franklin and Forman 1987), microclimatic effects may penetrate for as far as 160 m into a forest stand. Nest parasitism by brown-headed cowbirds and predation eggs and nestlings by small mammals, snakes, raptors and other birds increases for as much as 600 m from the edge (Gates and Gysel, 1978). Therefore, smaller patches, depending on their configuration, may be considered all "edge" .

Determining whether interior birds are responding to vegetational changes, competition and predation, or a combination of these will require additional studies that control for each of these variables in turn. However, there is good evidence that each of the above factors are related to edge. Since the quantity of edge is a product of stand size and shape, then findings such as those presented in this thesis that indicate stand size as a primary predictor of avian community diversity seem logical.

# CONCLUSIONS

In this study of eight forested patches, stand area was consistently the primary predictor of avian species diversity and richness. There is much agreement between this finding and those from studies conducted in forested landscapes elsewhere in the United States. This study also showed significant positive correlations between stand size and both shrub species richness and percent shrub cover as well as between percent shrub cover and bird species richness.

These findings may be useful when addressing land management policy issues. Ambuel and Temple (1983) cited guidelines embodying four major principles for managing fragmented landscapes for avian diversity: (1) one large island is superior to many small islands of the same area; (2) a compact island is superior to many small islands, the reasoning being that this reduces the ratio of edge to interior; (3) islands should be close together; (4) islands which are linked by narrow corridors are superior to isolated islands (Diamond 1975; Robbins 1979; Temple 1981 *in:* Ambuel and Temple 1983).

Galli et al. (1976) came to similar conclusions and added that maintenance of forested patches of 24 ha or greater is essential to preserving a complete regional avian community.

Though further study is needed to resolve questions concerning the relationhip between shrub layer measures, stand size and bird species richness, the above recommendations seem to be a good starting point for managing fragmented forested habitat for avian community diversity.

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# APPENDIX A

## BIRD SPECIES OBSERVED IN THE TUALATIN MOUNTAINS STUDY AREA

# BIRD SPECIES OBSERVED IN THE TUALATIN MOUNTAINS STUDY AREA

| Common name | Scientific name |
|---|---|
| American Robin | *Turdus migratoris* |
| Band-tailed Pidgeon | *Columba fasciata* |
| Bewick's Wren | *Thryomanes bewickii* |
| Black-capped Chickadee | *Parus atricapillus* |
| Black-headed Grosbeak | *Pheucticus melanocephalus* |
| Brown Creeper | *Certhia americana* |
| Bushtit | *Psaltiparus minimus* |
| Chestnut-backed Chickadee | *Parus rufescens* |
| Dark-eyed Junco | *Junco hyemaeis* |
| Downy Woopecker | *Picoides villosus* |
| Great Horned Owl | *Bubo virginianus* |
| Hairy Woodpecker | *Picoides pubescens* |
| Mourning Dove | *Zenaida macroura* |
| Olive-sided Flycatcher | *Contopus borealis* |
| Orange-crowned Warbler | *Vermivora celata* |
| Pacific-slope Flycatcher | *Empidonax difficilis* |
| Pileated Woodpecker | *Dryocopus pileatus* |
| Pine Siskin | *Carduelis pinus* |
| Purple Finch | *Carpodacus purpureus* |
| Red-breasted Nuthatch | *Sitta canadensis* |
| Red-tailed Hawk | *Buteo jamaicensis* |
| Ruby-crowned Kinglet | *Regulus calendula* |
| Ruffed Grouse | *Bonasa umbellus* |
| Rufous-sided Towhee | *Piplio erythrophthalmus* |
| Scrub Jay | *Aphelcoma coerulescens* |
| Song Sparrow | *Melospiza melodia* |
| Stellar's Jay | *Cyanocitta stellari* |
| Swainson's Thrush | *Catharus ustulatus* |
| Varied Thrush | *Ixoreus naevius* |
| Western Tanager | *Piranga ludoviciana* |
| Western Wood-peewee | *Conoptus sordidulus* |
| White-Crowned Sparrow | *Zonotricha leucophrys* |
| Wilson's Warbler | *Wilsonia pusilla* |
| Winter Wren | *Troglodytes troglodytes* |
| Yellow-rumped Warbler | *Dendroica coronata* |
| Yellow Warbler | *Dendroica petechia* |

Common and scientific names conform to those adopted by the Checklist Committee of the American Ornithologists Union as of 1990.

# APPENDIX B

# PLANT SPECIES COVERAGE BY TRANSECT AND PLOT

TRANSECT 1
Percent coverage

| Plant species | plot 1 | plot 2 | plot 3 | plot 4 | plot 5 |
|---|---|---|---|---|---|
| **Trees** | | | | | |
| *Tsuga heterophylla* | 0 | 40 | 0 | 5 | 5 |
| *Pseudotsuga menzesii* | 15 | 15 | 10 | 5 | 40 |
| *Abies grandis* | 3 | 3 | 10 | 4 | 0 |
| *Thuja plicata* | 1 | 4 | 3 | 15 | 15 |
| *Acer macrophyllum* | 20 | 10 | 35 | 55 | 40 |
| *Alnus rubra* | 3 | 4 | 45 | 15 | 0 |
| *Castanea sp.* | 30 | 0 | 0 | 0 | 0 |
| **Shrubs** | | | | | |
| *Acer circinatum* | 20 | 0 | 0 | 0 | 0 |
| *Berberis nervosa* | 15 | 15 | 30 | 15 | 20 |
| *Gaultheria shallon* | 5 | 60 | 0 | 2 | 2 |
| *Holodiscus discolor* | tr | 7 | 0 | tr | 1 |
| *Ilex aquilifolium* | 2 | 0 | 0 | 2 | 0 |
| *Oemleria cerasiformis* | 1 | tr | 3 | tr | tr |
| *Rhamnus purshiana* | 0 | 2 | 0 | 0 | 0 |
| *Rosa gymnocarpa* | tr | tr | 0 | 0 | 0 |
| *Rubus parviflorus* | 2 | 0 | 0 | 0 | 0 |
| *Rubus spectabilis* | 0 | 0 | 0 | 0 | 2 |
| *Rubus ursinus* | 0 | 0 | 0 | 2 | 1 |
| *Sambucus racemosa* | tr | 2 | 3 | 1 | 0 |
| *Sorbus aucuparia* | 0 | 0 | 0 | 0 | 0 |
| *Symphorocarpos alba* | 60 | 0 | 0 | 0 | 0 |
| *Vaccinium parvifolium* | 2 | 20 | 7 | tr | 5 |
| **Ground cover** | 0 | tr | 0 | 0 | 1 |
| *Asarum caudatum* | | | | | |
| *Athyrium filix-femina* | 0 | 0 | 2 | 0 | 0 |
| *Disporum hookeri* | tr | 0 | 0 | 0 | 0 |
| *Maianthemum diatatum* | 0 | 0 | 0 | 0 | 0 |
| *Montia sibirica* | tr | 0 | tr | 0 | 0 |
| *Oxalis oregana* | 0 | 0 | 0 | 1 | 2 |
| *Polystichum munitum* | 5 | 20 | 15 | 50 | 30 |
| *Pteridium aquilinum* | 0 | 0 | 2 | tr | tr |
| *Smilacena racemosa* | tr | 0 | 0 | 0 | 0 |
| *Smilacena stellata* | tr | 0 | 0 | 0 | 0 |
| *Trientalis latifolia* | 0 | 0 | 0 | 0 | 1 |
| *Trillium ovatum* | tr | tr | 0 | tr | tr |
| *Vancouveria hexandra* | 1 | 1 | 0 | 0 | 0 |
| *Viola glabella* | tr | 0 | 0 | 0 | 0 |
| Graminoids | 1 | tr | 10 | 0 | 0 |

TRANSECT 2

| **Plant species** | plot 1 | plot 2 | plot 3 | plot 4 | plot 5 |
|---|---|---|---|---|---|
| **Trees** | | | | | |
| *Acer macrophyllum* | 70 | 15 | 20 | 60 | 70 |
| *Alnus rubra* | 5 | 60 | 70 | 10 | 0 |
| *Prunus sp.* | 0 | 0 | 0 | 0 | 3 |
| *Thuja plicata* | 30 | 3 | 0 | 2 | 10 |
| *Tsuga heterophylla* | 0 | 5 | 0 | 0 | 0 |
| **Shrubs** | | | | | |
| *Acer circinatum* | 10 | 20 | 15 | 0 | 0 |
| *Berberis nervosa* | 0 | 0 | 0 | 0 | 0 |
| *Corylus cornuta* | 0 | 0 | 0 | 15 | 0 |
| *Oemlaria cerasiformis* | 0 | 0 | 0 | 1 | 3 |
| *Rubus discolor* | 0 | 0 | 0 | 0 | 60 |
| *Rubus parviflorus* | tr | 0 | 0 | 0 | 0 |
| *Rubus spectabilis* | 0 | 0 | 15 | 0 | 0 |
| *Rubus ursinus* | 3 | 0 | 0 | 12 | 15 |
| *Sambucus racemosa* | 15 | 4 | 0 | 0 | 1 |
| *Symphoricarpos albus* | 0 | 0 | 0 | tr | 0 |
| *Vaccinium parvifolium* | 0 | 1 | 4 | 0 | 0 |
| **Ground cover** | | | | | |
| *Asarum caudatum* | 0 | 0 | 0 | 0 | 0 |
| *Athyrium filix-femina* | 0 | 0 | 1 | 0 | 0 |
| *Disporum hookeri* | 0 | 1 | 0 | 0 | 0 |
| *Dryopteris austriaca (?)* | 0 | 1 | 0 | tr | 0 |
| *Geum macrophyllum* | 0 | 0 | 0 | 0 | tr |
| *Hydrophyllum tenuipes* | 0 | 0 | tr | 0 | tr |
| *Montia sibirica* | tr | 1 | 0 | 1 | 0 |
| *Osmorhiza chilensis* | tr | 0 | 0 | tr | tr |
| *Polypodium glycyrrhiza* | 0 | 4 | 0 | tr | 0 |
| *Polystichum munitum* | 20 | 50 | 7 | 20 | 10 |
| *Ranunculus repens* | 0 | 0 | 0 | 0 | 0 |
| *Rumex crispis* | tr | 0 | 0 | 0 | tr |
| *Smilacena racemosa* | tr | tr | 0 | tr | 0 |
| *Stachys cooleyi* | 0 | 0 | 0 | 0 | 0 |
| *Tellima grandiflora* | 1 | tr | 0 | tr | 0 |
| *Tolmeia menziesii* | 0 | 0 | 2 | tr | 0 |
| *Trillium ovatum* | 0 | 1 | 0 | 0 | 0 |
| *Viola glabella* | 0 | tr | 0 | 0 | 0 |
| Graminoids | 4 | tr | 1 | tr | tr |

TRANSECT 3

| **Plant species** | plot 1 | plot 2 | plot 3 | plot 4 | plot 5 |
|---|---|---|---|---|---|
| **Trees** | | | | | |
| *Abies grandis* | 5 | 0 | 0 | 0 | 0 |
| *Acer macrophyllum* | 45 | 0 | 35 | 35 | 60 |
| *Alnus rubra* | 0 | 65 | 40 | 10 | 0 |
| *Fraxinus latifolia* | 0 | 0 | 0 | 0 | 10 |
| *Prunus sp.* | 0 | 0 | 0 | 0 | 7 |
| *Pseudotsuga menziesii* | 70 | 1 | 10 | 15 | 5 |
| *Thuja plicata* | 0 | 25 | 0 | 20 | 5 |
| *Tsuga heterophylla* | 15 | tr | tr | 0 | 0 |
| **Shrubs** | | | | | |
| *Acer circinatum* | 30 | 80 | 12 | 0 | 0 |
| *Amelachier alnifolia* | 0 | 0 | 0 | 10 | 10 |
| *Berberis nervosa* | 25 | 50 | 14 | 20 | 13 |
| *Corylus cornuta* | 0 | 0 | 5 | 3 | 0 |
| *Gaultheria shallon* | 0 | 0 | 0 | 10 | 5 |
| *Hedera helix* | tr | 0 | 0 | 0 | 0 |
| *Holodiscus discolor* | 3 | 1 | 25 | 4 | 0 |
| *Ilex aquilifolium* | tr | 0 | 0 | 0 | 0 |
| *Rhamnus purshiana* | 1 | 0 | 2 | 0 | 2 |
| *Rosa gymnocarpa* | 0 | 0 | 0 | 15 | 1 |
| *Rubus parvfflorus* | 0 | 0 | 1 | 0 | 1 |
| *Rubus ursinus* | 5 | 0 | 7 | 0 | 5 |
| *Symphoricarpos albus* | 0 | 0 | 6 | 0 | 4 |
| *Vaccinium parvifolium* | 3 | 0 | 20 | 5 | 6 |
| **Ground cover** | | | | | |
| *Asarum caudatum* | 5 | 0 | 6 | 0 | 0 |
| *Disporum hookeri* | tr | tr | 0 | tr | 0 |
| *Polypodium glycrriza* | 0 | 0 | tr | 0 | 0 |
| *Polystichum munitum* | 65 | 30 | 17 | 5 | 30 |
| *Pteridium aquilinium* | tr | tr | 0 | tr | 0 |
| *Trillium ovatum* | 0 | 0 | tr | 0 | 0 |
| *Trientalis latifolia* | 0 | 0 | tr | 0 | tr |
| Graminoids | 0 | 0 | 3 | 0 | tr |

TRANSECT 4

| **Plant species** | plot 1 | plot 2 | plot 3 | plot 4 | plot 5 |
|---|---|---|---|---|---|
| **Trees** | | | | | |
| *Acer macrophyllum* | 40 | 25 | 15 | 50 | 35 |
| *Pseudotsuga menziesii* | 25 | 0 | 60 | 50 | 40 |
| *Alnus rubra* | 10 | 10 | 0 | 10 | 20 |
| *Thuja plicata* | 0 | 70 | 10 | 0 | 0 |
| *Abies grandis* | 0 | 0 | 50 | 7 | 5 |
| *Tsuga heterophylla* | 0 | 0 | 0 | 2 | 0 |
| **Shrubs** | | | | | |
| *Acer circinatum* | 10 | 10 | 20 | 0 | 0 |
| *Berberis nervosa* | 35 | 20 | 10 | 20 | 15 |
| *Gaultheria shallon* | 10 | 0 | 1 | 0 | 15 |
| *Rubus ursinus* | 10 | 2 | 1 | 10 | 3 |
| *Rubus discolor* | 5 | 0 | 0 | 0 | 0 |
| *Holodiscus discolor* | 0 | 5 | 0 | 3 | 1 |
| *Vaccinium parvifolium* | 5 | 15 | 5 | 20 | 7 |
| *Oemlaria cerasiformis* | 0 | 3 | 0 | 0 | tr |
| *Rosa gymnocarpa* | 2 | 2 | 2 | 2 | 0 |
| *Symphoricarpos albus* | 10 | tr | 0 | 2 | 0 |
| **Ground cover** | | | | | |
| *Polystichum munitum* | 30 | 60 | 10 | 30 | 30 |
| *Vancouveria hexandra* | 5 | 0 | 0 | 15 | 1 |
| *Asarum caudatum* | 3 | 0 | 0 | 0 | 2 |
| *Disporum hookeri* | 0 | 0 | tr | tr | 0 |
| *Osmorrhyza chilensis* | 0 | 0 | 0 | tr | 0 |
| *Smilacena stellata* | tr | 0 | tr | 0 | 0 |
| *Viola glabella* | tr | 0 | 0 | 0 | 0 |
| Graminoids | 1 | 0 | 0 | 2 | tr |

TRANSECT 5

| **Plant species** | plot 1 | plot 2 | plot 3 | plot 4 | plot 5 |
|---|---|---|---|---|---|
| **Trees** | | | | | |
| *Abies grandis* | 8 | 0 | tr | 12 | 35 |
| *Acer macrophyllum* | 20 | 10 | 0 | 25 | 40 |
| *Alnus rubra* | 2 | 20 | 0 | 20 | 7 |
| *Prunus sp.* | 3 | 0 | 0 | 0 | 0 |
| *Pseudotsuga menziesii* | 45 | 55 | 80 | 10 | 0 |
| *Thuja plicata* | 0 | 0 | 0 | 15 | 0 |
| **Shrubs** | | | | | |
| *Acer circinatum* | 35 | 75 | 7 | 15 | 10 |
| *Berberis nervosa* | 0 | 2 | 0 | 0 | 15 |
| *Corylus cornuta* | 0 | 0 | 0 | 0 | 0 |
| *Gaultheria shallon* | 0 | 0 | 7 | 2 | 5 |
| *Holodiscus discolor* | 0 | 0 | 0 | 0 | 0 |
| *Rosa gymnocarpa* | 1 | 0 | 4 | 5 | 0 |
| *Rubus lancinatus* | 0 | 0 | 0 | 0 | 0 |
| *Rubus ursinus* | 8 | 5 | 5 | 20 | 5 |
| *Sambucus racemosa* | 0 | 0 | 2 | 0 | 0 |
| *Symphoricarpos albus* | 3 | 0 | 0 | tr | 0 |
| *Vaccinium parvifolium* | tr | 0 | 5 | 0 | 2 |
| **Ground cover** | | | | | |
| *Achlys triphylla* | 0 | 0 | 4 | 0 | 0 |
| *Adenocaulon bicolor* | 1 | 0 | 0 | 0 | 0 |
| *Anaphalis margaritacea* | 0 | 0 | 0 | 0 | 0 |
| *Anemone deltoidea* | tr | 0 | 0 | tr | 0 |
| *Asarum caudatum* | 4 | 8 | 2 | 20 | 0 |
| *Athyrium filix-femina* | 0 | 0 | 0 | tr | 0 |
| *Cirsium arvense* | 0 | 0 | 0 | 0 | 0 |
| *Disporum hookeri* | 1 | 0 | tr | 0 | 1 |
| *Dryopteris austriaca* | 0 | tr | 0 | 0 | 1 |
| *Galium aparine* | 4 | tr | 1 | 2 | 1 |
| *Hypericum perforatum* | 0 | 0 | 0 | 0 | 0 |
| *Osmorrhyza chilensis* | 1 | 0 | 2 | 2 | 2 |
| *Polystichum munitum* | 10 | 35 | 7 | 50 | 30 |
| *Pteridium aquilineum* | 0 | 0 | 0 | 3 | 0 |
| *Smilacena stellata* | tr | 1 | tr | 1 | 0 |
| *Stellaria sp.* | 8 | 0 | 10 | 4 | 0 |
| *Trientalis latifolia* | tr | o | tr | 0 | 0 |
| *Trillium ovatum* | 0 | 0 | tr | 0 | tr |
| *Viola glabella* | 1 | 0 | 15 | tr | 0 |
| Graminoids | 12 | 10 | 0 | 5 | 5 |

# TRANSECT 6

| **Plant species** | plot 1 | plot 2 |
|---|---|---|
| **<u>Trees</u>** | | |
| *Acer macrophyllum* | 85 | 50 |
| *Alnus rubra* | 0 | 1 |
| *Pseudotsuga menziesii* | 0 | 30 |
| *Thuja plicata* | 10 | 10 |
| *Tsuga heterophylla* | 0 | 5 |
| **<u>Shrubs</u>** | | |
| *Acer circinatum* | 10 | 10 |
| *Berberis nervosa* | 0 | tr |
| *Corylus cornuta* | 0 | tr |
| *Crataegus sp.* | 2 | 1 |
| *Holodiscus discolor* | 0 | 3 |
| *Oemlaria cerasiformis* | 10 | 0 |
| *Rubus parviflorus* | 10 | 5 |
| *Vaccinium parvifolium* | 0 | 10 |
| **<u>Ground cover</u>** | | |
| *Disporum hookeri* | 0 | 5 |
| *Galium aparine* | 0 | 10 |
| *Geum macrophyllum* | tr | tr |
| *Hydrophyllum tenuipes* | 40 | 75 |
| *Polystichum munitum* | tr | 3 |
| *Pteridium aquilinium* | tr | 0 |
| *Rubus leucodermis* | 0 | 15 |
| *Rumex sp.* | 10 | 0 |
| *Smilecina stellata* | tr | 0 |
| *Taraxacum officinale* | 5 | 0 |
| *Tellima grandiflora* | 5 | 0 |
| *Trillum ovatum* | 0 | 1 |
| *Urtica lyallii* | 0 | 3 |
| *Vicia sp.* | 0 | 2 |
| *Viola glabella* | 2 | 15 |
| Graminoids | 15 | 10 |

TRANSECT 7

| **Plant species** | plot 1 | plot 2 | plot 3 | plot 4 | plot 5 |
|---|---|---|---|---|---|
| **Tree species** | | | | | |
| *Acer macrophyllum* | 25 | 25 | 30 | 80 | 20 |
| *Prunus sp.* | 35 | 0 | 0 | 0 | 0 |
| *Psuedotsuga menziesii* | 20 | 0 | 20 | 10 | 65 |
| *Alnus rubra* | 15 | 35 | 55 | 0 | 2 |
| *Abies grandis* | 0 | 0 | 10 | 0 | 2 |
| *Populus trichocarpa* | 0 | 0 | 10 | 0 | 0 |
| **Shurb species** | | | | | |
| *Acer circinatum* | 10 | 10 | 0 | 0 | 0 |
| *Berberis nervosa* | 10 | 10 | 15 | 5 | 20 |
| *Corylus cornutua* | 30 | 0 | 0 | 10 | 5 |
| *Gaultheria shallon* | 10 | 0 | 0 | 0 | 15 |
| *Holodiscus discolor* | 25 | 0 | 0 | 0 | 10 |
| *Oemlaria cerasiformis* | 0 | 0 | 15 | 5 | 0 |
| *Rosa gymnocarpa* | 15 | 0 | 0 | 5 | 5 |
| *Rubus parviflorus* | 20 | 15 | 20 | 40 | 35 |
| *Rubus ursinus* | 5 | 0 | 0 | 0 | 10 |
| *Sambucus racemosa* | 10 | 50 | 40 | 30 | 10 |
| *Vaccinium parvifolium* | | | | | |
| **Ground cover** | | | | | |
| *Adiantum pedatum* | 0 | 5 | 0 | 0 | 0 |
| *Athyrium filix-femina* | 0 | 5 | 0 | 0 | 5 |
| *Disporum hookeri* | 0 | 10 | 5 | 5 | 10 |
| *Equisetum hymale* | 0 | 10 | 0 | 0 | 0 |
| *Galium aparine* | 25 | 15 | 0 | 25 | 10 |
| *Geum macrophyllum* | 0 | 2 | 5 | 3 | 2 |
| *Hydrophyllum tenuipes* | 0 | 3 | 5 | 10 | 2 |
| *Lilium columbianum* | 2 | 0 | 2 | 2 | 0 |
| *Mitella ovalis* | 0 | 2 | 0 | 3 | 0 |
| *Montia sibirica* | 0 | 55 | 2 | 10 | 10 |
| *Polystichum munitum* | 10 | 30 | 25 | 10 | 15 |
| *Pteridium aquilinium* | 3 | 10 | 2 | 2 | 3 |
| *Ranunculus repens* | 0 | 2 | 0 | 2 | 0 |
| *Rubus lanciniatus* | 5 | 3 | 3 | 0 | 10 |
| *Rumex crispis* | 0 | 5 | 3 | 2 | 0 |
| *Tellima grandiflora* | 0 | 2 | 3 | 5 | 5 |
| Graminoids | 10 | 10 | 10 | 15 | 2 |

TRANSECT 8

| **Plant species** | Plot 1 | Plot 2 | Plot 3 |
|---|---|---|---|
| **Trees** | | | |
| *Acer macrophyllum* | 65 | 0 | 35 |
| *Alnus rubra* | 0 | 55 | 0 |
| *Pseudotsuga menzeisii* | 0 | 25 | 0 |
| *Thuja plicata* | 40 | 35 | 20 |
| **Shrubs** | | | |
| *Acer circinatum* | 0 | 10 | 15 |
| *Berberis nervosa* | 0 | 0 | 3 |
| *Gaultheria shallon* | tr | 20 | 0 |
| *Holodiscus discolor* | 5 | 3 | 2 |
| *Rubus ursinus* | 10 | 0 | 20 |
| *Sambucus racemosa* | 5 | 2 | 0 |
| *Symphorcarpos albus* | 15 | 2 | 0 |
| *Vaccinium parvifolium* | 0 | 5 | 0 |
| **Ground cover** | | | |
| *Achlys tripylla* | 3 | 5 | 0 |
| *Adenocaulon bicolor* | 15 | 0 | 0 |
| *Disporum hookeri* | 2 | 2 | 0 |
| *Geum macrophyllum* | 10 | 3 | 2 |
| *Hydrophyllum tenuipes* | 0 | 20 | 15 |
| *Montia sibirica* | 0 | 3 | 2 |
| *Osmorrhyza chilensis* | tr | tr | 2 |
| *Polystichum munitum* | 35 | 30 | 25 |
| *Pteridium aqulinium* | 3 | 0 | 0 |
| *Smilacena stellata* | 0 | 10 | 5 |
| *Trillium ovatum* | 5 | 2 | 5 |
| *Viola glabella* | 2 | 3 | 5 |
| Graminoids | 25 | 2 | 20 |

# APPENDIX C

# PLOT BY PLOT DATA SHEETS

| | PLOT | #TREE SPP | #SHRUB SPP | #GROUND COVER SPP | TREE COVER CLASS | %SHRUB COVER | %GROUND COVER | DISTANCE FROM EDGE | # Bird species |
|---|---|---|---|---|---|---|---|---|---|
| 1 | T1 P1 | 6 | 11 | 10 | 4 | 70 | 10 | 800 | 9 |
| 2 | T1 P2 | 6 | 8 | 6 | 5 | 95 | 20 | 900 | 11 |
| 3 | T1 P3 | 5 | 4 | 4 | 6 | 25 | 30 | 1000 | 9 |
| 4 | T1 P4 | 5 | 8 | 8 | 6 | 40 | 50 | 1100 | 11 |
| 5 | T1 P5 | 4 | 9 | 7 | 6 | 30 | 35 | 1200 | 9 |
| 6 | T2 P1 | 3 | 1 | 8 | 5 | 25 | 30 | 100 | 8 |
| 7 | T2 P2 | 3 | 3 | 10 | 5 | 25 | 60 | 200 | 7 |
| 8 | T2 P3 | 1 | 3 | 5 | 4 | 30 | 10 | 300 | 7 |
| 9 | T2 P4 | 3 | 4 | 7 | 4 | 30 | 25 | 400 | 11 |
| 10 | T2 P5 | 2 | 4 | 5 | 5 | 75 | 10 | 200 | 9 |
| 11 | T3 P1 | 5 | 7 | 4 | 6 | 65 | 70 | 100 | 8 |
| 12 | T3 P2 | 3 | 3 | 2 | 5 | 110 | 30 | 200 | 10 |
| 13 | T3 P3 | 3 | 9 | 6 | 5 | 75 | 25 | 300 | 7 |
| 14 | T3 P4 | 3 | 6 | 3 | 5 | 40 | 5 | 400 | 11 |
| 15 | T3 P5 | 6 | 9 | 3 | 4 | 40 | 30 | 500 | 8 |
| 16 | T4 P1 | 3 | 8 | 6 | 4 | 85 | 40 | 100 | 11 |
| 17 | T4 P2 | 3 | 8 | 1 | 6 | 55 | 60 | 200 | 11 |
| 18 | T4 P3 | 4 | 6 | 3 | 6 | 40 | 10 | 300 | 8 |
| 19 | T4 P4 | 5 | 6 | 5 | 5 | 55 | 50 | 400 | 14 |
| 20 | T4 P5 | 4 | 6 | 4 | 4 | 40 | 35 | 500 | 11 |
| 21 | T5 P1 | 5 | 5 | 12 | 5 | 45 | 40 | 100 | 9 |
| 22 | T5 P2 | 2 | 3 | 5 | 5 | 80 | 45 | 200 | 8 |
| 23 | T5 P3 | 2 | 6 | 12 | 5 | 30 | 45 | 250 | 6 |
| 24 | T5 P4 | 5 | 5 | 8 | 5 | 40 | 85 | 50 | 5 |
| 25 | T5 P5 | 4 | 5 | 7 | 4 | 30 | 35 | 100 | 6 |
| 26 | T6 P1 | 2 | 4 | 11 | 5 | 25 | 120 | 0 | 13 |
| 27 | T6 P2 | 5 | 6 | 12 | 5 | 50 | 100 | 0 | 8 |
| 28 | T7 P1 | 1 | 10 | 5 | 5 | 125 | 50 | 400 | 11 |
| 29 | T7 P2 | 2 | 6 | 15 | 4 | 110 | 45 | 600 | 16 |
| 30 | T7 P3 | 4 | 6 | 10 | 6 | 70 | 55 | 700 | 17 |
| 31 | T7 P4 | 2 | 10 | 12 | 5 | 90 | 85 | 800 | 16 |
| 32 | T7 P5 | 1 | 10 | 10 | 5 | 110 | 80 | 500 | 11 |
| 33 | T8 P1 | 2 | 4 | 10 | 5 | 35 | 100 | 0 | 7 |
| 34 | T8 P2 | 3 | 6 | 8 | 5 | 40 | 80 | 50 | 9 |
| 35 | T8 P3 | 2 | 4 | 9 | 6 | 40 | 85 | 75 | 8 |

| | SHANNON'S INDEX | STAND SIZE | Swainson's thrush | CB chickadee | BC chickadee | blkhd grosbeak | wilson's wrblr | os flycthr | rs towhee | de junco | dwny wdpkr | yr wblr | oc wblr |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 2.072 | 18 | 2 | 0 | 1 | 0 | 0 | 0 | 1 | 3 | 0 | 0 | 0 |
| 2 | 2.235 | 18 | 3 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 0 | 1 | 2 |
| 3 | 1.902 | 18 | 3 | 10 | 0 | 1 | 1 | 0 | 0 | 0 | 0 | 1 | 0 |
| 4 | 2.267 | 18 | 1 | 3 | 1 | 1 | 0 | 0 | 1 | 0 | 0 | 0 | 0 |
| 5 | 1.707 | 18 | 2 | 0 | 0 | 0 | 1 | 0 | 0 | 6 | 0 | 1 | 1 |
| 6 | 2.021 | 2 | 2 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 1 | 0 | 0 |
| 7 | 1.731 | 2 | 3 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |
| 8 | 1.813 | 2 | 3 | 0 | 0 | 0 | 2 | 0 | 0 | 2 | 0 | 0 | 0 |
| 9 | 2.298 | 2 | 2 | 0 | 1 | 0 | 1 | 0 | 1 | 3 | 0 | 1 | 1 |
| 10 | 578 | 2 | 2 | 1 | 1 | 0 | 1 | 0 | 0 | 1 | 0 | 0 | 0 |
| 11 | 1.937 | 14 | 2 | 8 | 0 | 2 | 2 | 3 | 4 | 3 | 0 | 0 | 0 |
| 12 | 3.111 | 14 | 1 | 4 | 0 | 0 | 1 | 0 | 3 | 0 | 1 | 1 | 1 |
| 13 | 1.816 | 14 | 0 | 0 | 0 | 0 | 2 | 0 | 1 | 0 | 0 | 1 | 0 |
| 14 | 2.009 | 14 | 2 | 10 | 1 | 0 | 1 | 2 | 0 | 0 | 1 | 1 | 0 |
| 15 | 1.791 | 14 | 2 | 7 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 1 |
| 16 | 2.316 | 24 | 3 | 0 | 0 | 3 | 1 | 0 | 3 | 3 | 0 | 0 | 3 |
| 17 | 2.071 | 24 | 1 | 9 | 0 | 2 | 1 | 0 | 0 | 2 | 0 | 1 | 0 |
| 18 | 2.006 | 24 | 2 | 2 | 0 | 1 | 0 | 0 | 1 | 2 | 0 | 0 | 0 |
| 19 | 2.456 | 24 | 1 | 5 | 1 | 2 | 0 | 0 | 0 | 1 | 0 | 1 | 0 |
| 20 | 2.250 | 21 | 4 | 0 | 0 | 1 | 1 | 0 | 1 | 2 | 0 | 1 | 0 |
| 21 | 1.825 | 7 | 1 | 0 | 0 | 0 | 1 | 0 | 1 | 0 | 0 | 0 | 1 |
| 22 | 1.871 | 7 | 1 | 3 | 0 | 0 | 0 | 0 | 0 | 2 | 0 | 0 | 0 |
| 23 | 1.467 | 7 | 2 | 0 | 0 | 0 | 2 | 0 | 0 | 0 | 0 | 0 | 0 |
| 24 | 1.414 | 7 | 1 | 5 | 0 | 0 | 0 | 0 | 0 | 2 | 0 | 0 | 0 |
| 25 | 1.813 | 7 | 3 | 2 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 |
| 26 | 2.313 | 1 | 1 | 3 | 0 | 0 | 1 | 0 | 4 | 1 | 0 | 0 | 0 |
| 27 | 1.930 | 1 | 1 | 0 | 0 | 0 | 1 | 0 | 0 | 3 | 0 | 0 | 0 |
| 28 | 2.112 | 40 | 3 | 3 | 0 | 0 | 3 | 0 | 2 | 3 | 0 | 0 | 0 |
| 29 | 2.467 | 40 | 3 | 3 | 0 | 1 | 1 | 0 | 3 | 5 | 1 | 0 | 2 |
| 30 | 2.491 | 40 | 1 | 1 | 1 | 0 | 3 | 1 | 3 | 13 | 1 | 0 | 0 |
| 31 | 2.054 | 40 | 1 | 1 | 1 | 2 | 3 | 0 | 7 | 2 | 0 | 0 | 1 |
| 32 | 2.252 | 40 | 3 | 3 | 0 | 1 | 1 | 0 | 3 | 0 | 0 | 0 | 0 |
| 33 | 1.530 | 1 | 0 | 18 | 0 | 0 | 0 | 1 | 1 | 5 | 0 | 0 | 0 |
| 34 | 1.992 | 1 | 0 | 2 | 0 | 10 | 0 | 0 | 1 | 1 | 0 | 0 | 0 |
| 35 | 1.816 | 1 | 1 | 4 | 0 | 0 | 0 | 0 | 0 | 4 | 0 | 0 | 0 |

| | w wd peewee | stlr's jay | pltd wdpkr | w. tnagr | wtr wren | rb nuthch | bwk wren | vrd thrush | wc sprow | y r wblr | gh owl | r grouse | pne sskn | m dove | p fnch | s sprw | hry wdpkr | b-t pign | bsh tit | rc knglt |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 0 | 0 | 0 | 0 | 3 | 0 | 0 | 0 | 0 | 0 | 1 | 7 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 |
| 2 | 2 | 0 | 0 | 0 | 4 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 5 | 1 | 0 | 0 | 0 | 0 | 8 | 0 |
| 3 | 0 | 0 | 0 | 0 | 3 | 0 | 0 | 1 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 5 | 0 |
| 4 | 4 | 0 | 1 | 0 | 2 | 1 | 0 | 2 | 0 | 0 | 0 | 0 | 6 | 0 | 1 | 0 | 0 | 0 | 0 | 0 |
| 5 | 3 | 0 | 1 | 0 | 3 | 0 | 0 | 4 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 |
| 6 | 1 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 7 | 0 | 0 | 0 | 0 | 2 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 0 | 0 | 7 | 0 |
| 8 | 0 | 0 | 0 | 0 | 3 | 1 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 |
| 9 | 1 | 0 | 0 | 0 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 |
| 10 | 1 | 0 | 0 | 0 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 |
| 11 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 12 | 1 | 0 | 1 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 13 | 1 | 0 | 0 | 0 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 14 | 0 | 3 | 0 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 15 | 2 | 0 | 0 | 0 | 3 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 16 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 4 | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 0 | 0 | 0 | 0 |
| 17 | 3 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 5 | 0 |
| 18 | 3 | 0 | 1 | 0 | 2 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 19 | 1 | 0 | 1 | 0 | 2 | 1 | 0 | 1 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 |
| 20 | 2 | 0 | 0 | 0 | 1 | 1 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 21 | 3 | 0 | 0 | 0 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 9 |
| 22 | 1 | 0 | 0 | 0 | 6 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 5 | 0 |
| 23 | 1 | 0 | 0 | 0 | 7 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 |
| 24 | 1 | 0 | 0 | 0 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 25 | 2 | 0 | 0 | 0 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 26 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 3 | 0 | 0 | 5 | 0 | 0 | 3 | 0 | 0 | 7 | 0 |
| 27 | 0 | 0 | 0 | 0 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 |
| 28 | 0 | 0 | 0 | 0 | 2 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 3 | 0 | 0 | 4 | 0 |
| 29 | 0 | 1 | 1 | 0 | 2 | 1 | 2 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 1 | 0 | 0 | 0 | 0 |
| 30 | 1 | 0 | 0 | 0 | 3 | 2 | 0 | 0 | 0 | 1 | 0 | 0 | 3 | 0 | 0 | 2 | 0 | 0 | 10 | 0 |
| 31 | 0 | 0 | 0 | 0 | 3 | 1 | 0 | 0 | 0 | 1 | 0 | 0 | 5 | 0 | 0 | 1 | 0 | 0 | 5 | 0 |
| 32 | 0 | 3 | 3 | 0 | 0 | 2 | 0 | 1 | 0 | 0 | 0 | 0 | 5 | 0 | 0 | 4 | 0 | 0 | 0 | 0 |
| 33 | 1 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 10 | 0 |
| 34 | 2 | 0 | 0 | 0 | 3 | 0 | 0 | 0 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 35 | 1 | 0 | 0 | 0 | 3 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |

| | ps flycthr | crow | robn | cdr wxwg | hse fnch | r-t hawk | brn crpr | plot' |
|---|---|---|---|---|---|---|---|---|
| 1 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | T1 P1 |
| 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | T1 P2 |
| 3 | 0 | 0 | 2 | 0 | 0 | 0 | 0 | T1 P3 |
| 4 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | T1 P4 |
| 5 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | T1 P5 |
| 6 | 2 | 0 | 1 | 0 | 0 | 0 | 0 | T2 P1 |
| 7 | 0 | 0 | 3 | 0 | 0 | 0 | 0 | T2 P2 |
| 8 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | T2 P3 |
| 9 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | T2 P4 |
| 10 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | T2 P5 |
| 11 | 0 | 0 | 2 | 0 | 0 | 0 | 0 | T3 P1 |
| 12 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | T3 P2 |
| 13 | 0 | 0 | 3 | 0 | 0 | 0 | 0 | T3 P3 |
| 14 | 0 | 0 | 3 | 0 | 0 | 0 | 0 | T3 P4 |
| 15 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | T3 P5 |
| 16 | 0 | 0 | 4 | 0 | 0 | 0 | 0 | T4 P1 |
| 17 | 0 | 0 | 2 | 0 | 0 | 0 | 0 | T4 P2 |
| 18 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | T4 P3 |
| 19 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | T4 P4 |
| 20 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | T4 P5 |
| 21 | 0 | 0 | 3 | 0 | 0 | 0 | 0 | T5 P1 |
| 22 | 0 | 0 | 4 | 0 | 0 | 0 | 0 | T5 P2 |
| 23 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | T5 P3 |
| 24 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | T5 P4 |
| 25 | 0 | 0 | 4 | 0 | 0 | 0 | 0 | T5 P5 |
| 26 | 0 | 0 | 11 | 4 | 4 | 0 | 0 | T6 P1 |
| 27 | 0 | 0 | 3 | 0 | 3 | 0 | 0 | T6 P2 |
| 28 | 1 | 0 | 4 | 0 | 0 | 0 | 0 | T7 P1 |
| 29 | 2 | 0 | 1 | 0 | 0 | 0 | 0 | T7 P2 |
| 30 | 0 | 0 | 3 | 0 | 0 | 1 | 0 | T7 P3 |
| 31 | 1 | 0 | 4 | 0 | 0 | 0 | 0 | T7 P4 |
| 32 | 0 | 0 | 3 | 0 | 0 | 0 | 1 | T7 P5 |
| 33 | 0 | 5 | 0 | 0 | 0 | 0 | 0 | T8 P1 |
| 34 | 0 | 0 | 3 | 0 | 0 | 0 | 0 | T8 P2 |
| 35 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | T8 P3 |